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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF BIOGUARDIAN® AEROSOL SAMPLERS

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In this study, sampler characteristics and sampling efficiency measurements of three BioGuardian® air samplers were determined. BioGuardian® 1.02 (BG1) has 1 cyclone and an air flow rate of 88 L/min; BioGuardian® 4.02 (BG4) has 4 cyclones and an air flow rate of 350 L/min; BioGuardian® 12.02 (BG12) has 12 cyclones and an air flow rate of 1000 L/min. The sampling efficiency tests were conducted using 1- and 2-µm polystyrene latex (PSL) microspheres, and 4 and 6 µm sodium fluorescein tagged oleic acid (fluorescent oleic acid) particles. The analysis was by fluorometry. The power usage of BG1, BG4, and BG12 are 58, 137, and 421 W, respectively. The sampling efficiency results show that BG1, BG4, and BG12 have peaks of 51.5% ± 6.4, 48.6% ± 2.5, and 31.7% ± 4.7, respectively, for 2-µm particles compared to reference filter samples.

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PREFACE

The work described in this report was authorized under Project No. 622384/ACB2, Non-Medical CB Defense. The work was started in June 2002 and completed in July 2002.

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CHARACTERISTICS AND SAMPLING EFFICIENCIES
OF BIOGUARDIAN® AEROSOL SAMPLERS

1. INTRODUCTION

This technical note is one in a continuing series of short reports intended to document and preserve the record of data from characterizing aerosol collector technology. These reports are only "snapshots" of progress as part of a DoD technology watch on the evolution of a critical supporting technology for biodetection capability. This is not intended to be a comprehensive study or analysis – look for documents in the technical report series for such. A technical note simply records a limited set of observations and provides the company that furnished the device for characterization, a record of the data measured.

Air samplers are gaining importance in the war against terrorism and on battlefields to detect the presence of chemical, biological, and nuclear aerosols. Samplers and detection systems must be tested, and their performance efficiencies determined so that suitable samplers and detectors can be used for each condition. Knowledge of equipment performance enhances the ability to protect soldiers, first responders, and the general public.

Air samplers for biological material must collect them in a gentle manner to reduce destruction to the organism if the analysis method requires the organism to be alive. Vegetative bacteria may be killed if collected dry. Therefore, to reduce organism drying, samplers may collect biological material in liquid. An ideal biological sampler should be small, portable, use minimal power, and have a high sampling efficiency.

In this study, characteristics, sampling efficiencies, and concentration factors of three BioGuardian® aerosol samplers were evaluated: BioGuardian® 1.02 (BG1), BioGuardian® 4.02 (BG4), and BioGuardian® 12.02 (BG12). All three samplers were manufactured by InnovaTek, Incorporated, Richland, WA. Each sampler's characteristics (e.g., size, weight, air flow rate, and power consumption) were measured. Sampling efficiency experiments were conducted in a 70-m^3 chamber at the U.S. Army Edgewood Chemical Biological Center (ECBC). The concentration factor of the samplers was also determined.

These samplers were only available for 1 week of testing. Therefore, the number of tests and the number of particle sizes tested were limited. Some sampler characteristics were not measured due to the time limitation. Only one of each sampler was available for testing; therefore, the variations in sampling efficiency between samplers were not determined.

The performance of an aerosol sampler is the product of the sampler's aspiration, transmission, and collection efficiencies. The aspiration efficiency of a sampler gives the efficiency with which particles enter into the sampler inlet. Transmission efficiency gives the efficiency with which the particles are transported to the collection point, and the collection efficiency gives the efficiency with which particles are captured and retained by the sampling medium. In this study, the samplers were tested in an environmentally controlled chamber at calm air conditions and do not include inlet efficiencies at varying wind velocities. The concentration factor of the samplers was also calculated. This factor is defined as sampling efficiency multiplied by the ratio of air volume sampled to output liquid volume.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

Sampler characterization tests were conducted in a 70-m^3 bio-safety Level 1 chamber. Chamber temperature and humidity can be set and maintained easily and accurately by a computer. Power receptacles inside the chamber are also controlled by this computer.

To achieve very low particle concentrations in the chamber, HEPA filters are installed at the inlet to filter air entering the chamber. Similarly, HEPA filters are installed at the exhaust port to filter all particles leaving the chamber. The aerosol concentration in the chamber is reduced by exhausting chamber air through the HEPA filters, and by pumping HEPA filtered air into the chamber. The maximum amount of air flow that can be exhausted from the chamber by the exhaust pump is approximately 2×10^4 L/min. There is also a small re-circulation system that removes air from the chamber, passes it through a HEPA filter, and delivers it back to the chamber. This system is useful when the aerosol concentration in the chamber needs to be reduced by a small amount.

Aerosols can be either generated outside and delivered to the chamber or can be generated inside the chamber. The chamber air is mixed by a fan after and/or during the aerosol generation to achieve uniform aerosol concentration in the chamber. Previous tests showed that mixing the aerosol in the chamber for 1 min is adequate to achieve uniform aerosol concentration.

2.2 BioGuardian® 1.02 (BG1).

A picture of the BG1 is shown in Figure 1. this sampler has one wetted wall cyclone for aerosol collection. The collection mechanism is by inertial impaction. The air inlet is a rectangular opening that is opened to the atmosphere. The designed air flow is 90 L/min; however, the measured air flow rate was 88 L/min. This sampler weighs 17 lb, is 11 ¾ in. long, 11 in. wide, and 17 ¼ in. high. The BG1 sampler is designed to produce 10 cm^3 of liquid sample. Power usage during sampling was 57.5 W.

2.3 BioGuardian® 4.02 (BG4).

A picture of the BG4 is shown in Figure 2. This sampler has four wetted wall cyclones for aerosol collection. The designed air flow rate is 350 L/min; but, the measured air flow rate was 350.9 L/min. This sampler weighs approximately 33 lb, is 12 in. long, 10 in. wide, and 18 in. tall. The BG4 sampler is designed to produce 10 cm^3 of liquid sample. Power usage during sampling was 137 W.

2.4 BioGuardian® 12.02 (BG12).

A picture of the BG12 is shown in Figure 3. The sampler has 12 wetted wall cyclones for aerosol collection. There is a pre-separator to remove large particles before the air enters the cyclones. The designed air flow rate is 1100 L/min; however, the air flow rate measured at InnovaTek was 1000 L/min. The air flow rate was not measured at ECBC due to technical difficulties. The BG12 is a cylindrical sampler that weighs more than 75 lb, is 25 in. tall, and 14.5 in. in diameter. Power usage during sampling was 421 W.

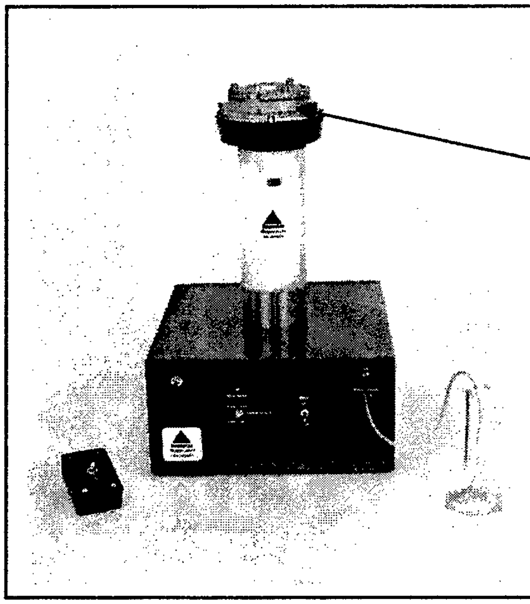

Figure 1. BioGuardian® 1.02

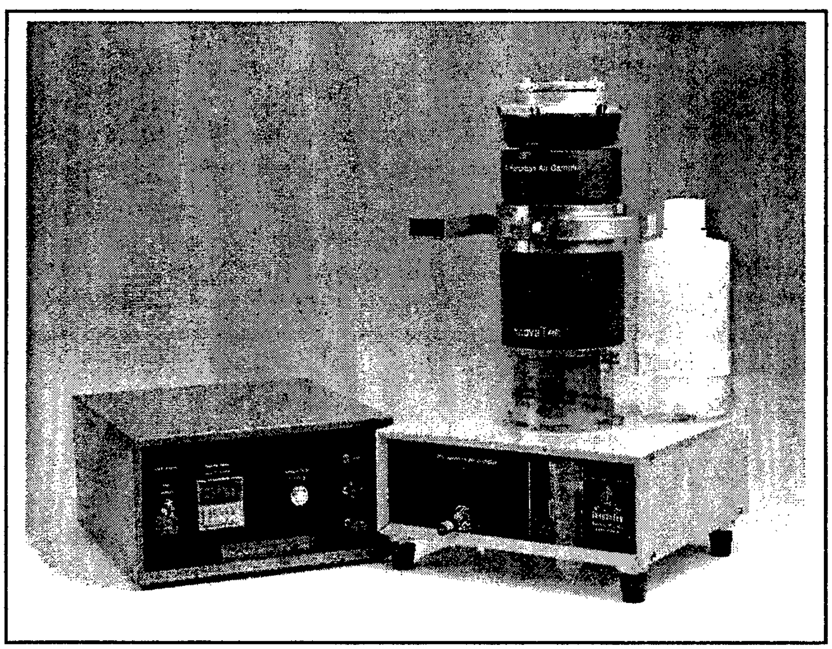

Figure 2. BioGuardian® 4.02

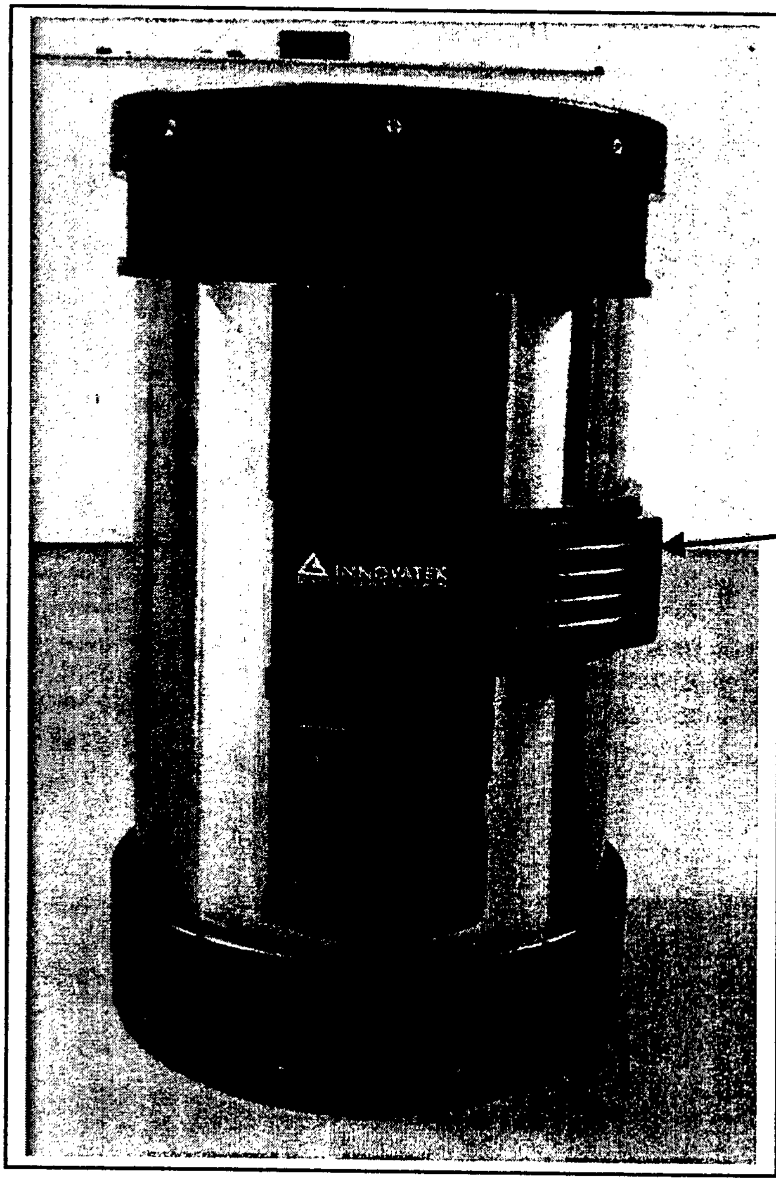

Figure 3. BioGuardian® 12.02

Air inlet

2.5 Sampler Characteristics' Measurements.

The air flow rates of the reference filters and samplers were measured using a Buck calibrator (A.P. Buck, Incorporated, Orlando, FL) and Kurz air flow meter (Kurz Instruments, Incorporated, Monterey, CA). The air flow rate for BG12 was not measured at ECBC because of technical difficulties. Using a power meter (Extech Instruments, Taiwan), investigators measured the weight and dimensions of the samplers along with power usage.

3. TEST PROCEDURES AND ANALYSIS

3.1 Sampling Efficiency Measurements.

The samplers and corresponding reference filters sampled the air simultaneously and for the same amount of time. Earlier tests were conducted with 10-min sampling times; however, another sampler that was characterized with the BioGuardians® did not function well with a 10-min sampling time; therefore, later tests were conducted with 5-min sampling times. Tests with no aerosols were conducted to determine background fluorescence of the samplers as well as reference filters. In addition, prewashes were conducted before each test to confirm that the samplers were free of fluorescent material. After the first sampling test, up to four washes were conducted to remove the fluorescent material from the samplers, and to determine the number of washes required to remove all fluorescent material from the sampler after each test.

Sampling efficiency tests were conducted with two kinds of aerosols and processing methods. The first method used monodisperse fluorescent PSL microspheres. The second method used monodisperse fluorescent oleic acid particles. Both aerosol generation and processing methods are described in detail below.

3.2 Polystyrene Latex Microsphere (PSL) Tests.

Sampling efficiency tests were conducted with 1-, and 2-µm blue fluorescent PSL microspheres (Duke Scientific Corporation, Palo Alto, CA). The PSL aerosol was generated using a 36 jet Collison nebulizer, then passed through a radioactive isotope (Kr-85) neutralizer to reduce the charge on the particles. During the experiment, aerosol was generated for 10-20 min and mixed for 1 min before sampling.

The samplers and the corresponding reference filters sampled the PSL aerosol simultaneously and for the same amount of time. Polycarbonate membrane filters (Osmonics Incorporated, Minnetonka, MN) were used as reference filters to collect the fluorescent PSL microspheres. All samplers used the manufacturer's recommended liquid for collecting PSL microspheres. After sampling, the sample liquid and reference filters were collected. Sample liquids were directly analyzed by the fluorometer; however, the membrane filters were processed to remove microspheres from the filters into the liquid for fluorometer analysis (Kesavan and Doherty 1999).[1] The removal procedure consists of placing the membrane filters into 15 mL of filtered deionized water, then hand shaking the solution for 10 s followed by vortexing it for 50 s. The 60 s of hand shaking and 50 s of vortexing were repeated four times (total of 5 min) to completely remove fluorescent PSL microspheres from the membrane filters.

3.3 Sodium Fluorescein Tagged Oleic Acid (Fluorescent Oleic Acid) Tests.

Sampling efficiency tests were also conducted with 4 and 6 μm fluorescent oleic acid particles. The monodisperse fluorescent oleic acid particles were generated using a Vibrating Orifice Aerosol Generator (VOAG, TSI Incorporated, St. Paul, MN). As with the PSL tests, the generated aerosol was passed through a Kr–85 radioactive isotope neutralizer to eliminate charge on particles, and then delivered to the chamber. Sizes of the fluorescent oleic acid particles were determined by sampling the aerosol onto a microscope slide inserted into an impactor, and then measuring the droplet size using a microscope. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al., 1982)[2] and the density of fluorescent oleic acid. At the end of aerosol generation, the aerosol in the chamber was mixed for 1 min before sampling. The samplers and the corresponding reference filters sampled the aerosol simultaneously and for the same amount of time. The samplers used the manufacturer's supplied liquid. Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as the reference filters to collect fluorescent oleic acid particles.

Samples from the BioGuardian® samplers were corrected for pH by adding NH_4OH before measurement by the fluorometer (Barnstead/Thermolyne, Dubuque, IA). Glass fiber filters were removed from filter holders, placed into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Incorporated, Melrose Park, IL) for 1 hr. The recovery solution used in the tests had water with a pH between 8 and 10, and was obtained by adding a small amount of NH_4OH (e.g., 1000 mL of water with 0.563 mL of 14.8 N NH_4OH). Factors that affect fluorescein analysis and the removal of fluorescein from filters are described in detail by Kesavan et al. (2001).[3] The fluorescence of the solution was measured using a fluorometer. All the samples were analyzed the same day as the experiment or the next day.

3.4 Analysis.

The sampling efficiency was determined by comparing the fluorometer measured fluorescence of the sampler liquids to the reference filters. The air flow rate of the samplers and the reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation. The concentration factor is calculated by multiplying the sampling efficiency by the ratio of sampled air volume to liquid sample volume. Because we used 5-min and 10-min sampling times, we calculated the concentration factor using a 1-min sampling time.

4. RESULTS

The sampler characteristics, sampling efficiency, and concentration factor results of BG1, BG4, and BG12 are shown in the table and Figure 4. The sampling efficiency results of BG1 show a peak of 51.5% ± 6.4 for 2-μm particles. The BG4 sample had a peak of 48.6% ± 2.5 for 2-μm particles, and BG12 has a peak of 31.7% ± 4.7 for 2-μm particles. The average liquid output volume of BG1 was 7.7 ± 0.5 mL, of BG2 was 12.6 ± 2.3 mL, and of BG3 was 11.6 ± 1.3 mL. The concentration factors are listed in the table.

5. DISCUSSION

Sampler characteristics and sampling efficiency measurements of BioGuardian® 1.02 (BG1), BioGuardian® 4.02 (BG4), and the BioGuardian® 12.02 (BG12) were determined in this study using 1- and 2-μm PSL microspheres, and 4 and 6 μm fluorescent oleic acid particles. The results show

Table. Sampler Characteristics and Efficiencies for BG1, BG4, and BG12.

	BioGuardian® 1	*BioGuardian® 4*	*BioGuardian® 12*
Number of Cyclones	1	4	12
Designed air flow rate (L/min)	90	350	1100
Measured air flow rate (L/min)	88 (measured at ECBC)	350.9 (measured at ECBC)	1000 (measured at InnovaTek)
Power, measured at ECBC (Watts)	57.5	137	421
Weight (lb)	17	32.5	> 75
Dimensions (in.)	Length = 11 ¾ Width = 11 . Height = 17 ¼	Length = 12 Width = 10 Height = 18	Height = 25 Diameter = 14.5
Sample Volume, (mL)	7.7 ± 0.5	11.6 ± 1.3	12.6 ± 2.3
Particle Size (μm)	***Sampling Efficiency (%) ± one standard deviation***		
1	21.2 ±0.6	33.8 ±1.8	26.5 ±3.4
2	51.5 ±6.4	48.6 ±2.5	31.7 ±4.7
4	38.8 ±0.9	47.4 ±1.2	31.9 ±1.2
6	39.9 ±6.9	42.8 ±4.0	25.8 ±2.7
Particle Size (μm)	***Concentration Factor for 1 min***		
1	$0.2 * 10^4$	$1.0 * 10^4$	$2.1 * 10^4$
2	$0.6 * 10^4$	$1.5 * 10^4$	$2.5 * 10^4$
4	$0.4 * 10^4$	$1.4 * 10^4$	$2.5 * 10^4$
6	$0.6 * 10^4$	$1.3 * 10^4$	$2.0 * 10^4$

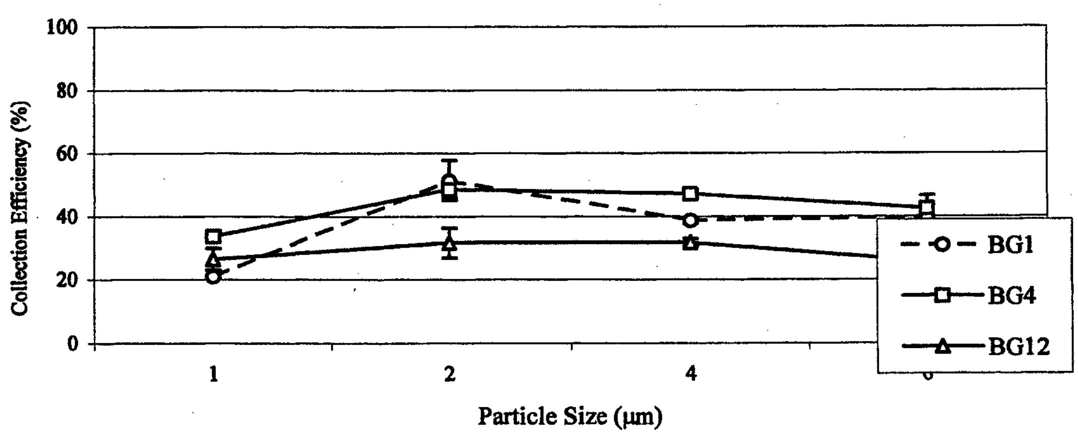

Figure 4. Sampling Efficiencies for BG1, BG4, and BG12

that BG1, BG4, and BG12 have peak efficiencies of 51.5% ± 6.4, 48.6% ± 2.5, and 31.7 % ± 4.7, respectively, for 2-μm particles. The highest concentration factors for BG1, BG4, and BG12 are 0.6 $*10^4$, 1.5 $* 10^4$, 2.5 $* 10^4$ per minute, respectively, for 2-μm particles.

Prewashes were conducted to confirm that the samplers were free of fluorescent material before each test. In general, there were very small amounts of fluorescent material in the prewash solutions, and corrections were not made for this small amount.

The air flow rates of BG1 and BG4 were measured at ECBC; however, the air flow rate of BG12 was not measured at ECBC due to technical difficulties. The air flow rate measured by the manufacturer for BG12 was used in the sampling efficiency calculations. The air flow rate for BG12 was measured at the exhaust by the manufacturer, and they observed some leaks that bypassed the cyclones, entered the pump, and came out with the exhaust. If the air flow rate through the cyclone is less than what was measured at the exhaust, then the sampling efficiency will be higher.

The concentration factor of the samplers was calculated from the sampling efficiency result, air flow rate of the sampler, and the liquid volume. Because two different sampling times were used in these tests (10 and 5 min), the concentration factor was determined for 1 min air sampling. All three BioGuardian® air samplers maintain a constant sample liquid volume that is re-circulated; therefore, the concentration factor will increase proportionally to the sampling time.

6. CONCLUSIONS

Aerosol samplers BioGuardian® 1.02 (BG1), BioGuardian® 4.02 (BG4), and BioGuardian® 12.02 (BG12) were characterized at the U.S.Army Edgewood Chemical Biological Center for 1 week. The results show that BG1, BG4, and BG12 have peak efficiencies of 51.5% ± 6.4, 48.6% ± 2.5, and 31.7 % ± 4.7, respectively, for 2-μm particles. The concentration factors for BG1, BG4, and BG12 are 0.6 $* 10^4$, 1.5 $* 10^4$, and 2.5 $* 10^4$ per minute, respectively, for 2-μm particles.

These samplers were provided by InnovaTek, Incorporated, Richland, WA, and were only available for testing for 1 week; therefore, the number of particle sizes and the number of tests were limited. Some of the sampler characteristics were not measured due to time limitations. Only one of each sampler was available for testing. Therefore, these results do not show what variations might be expected between samplers of the same model.

Information (e.g., sampling efficiency, concentration factor, size, weight, air flow rate, and power consumption of the samplers) is given in Section 4. The decision of considering a sampler for an application will have to include all the above mentioned information. Readers are advised that some of these samplers may be modified and/or improved based on these test results and are improved as new technology becomes available. Therefore, a modified or improved sampler may have very different characteristics than those presented in this report.

LITERATURE CITED

1. Kesavanathan, J.; Doherty, R.W. *Test Procedure for Removing Polystyrene Latex Microspheres from Membrance Filters*; ECBC-TN-001; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 1999; UNCLASSIFIED Report (AD-A367979).

2. Olan-Figueroa, E.; McFarland, A.R.; Ortiz, C.A. Flattening Coefficients for DOP and Oleic Acid Droplets Deposited on Treated Glass Slides; *Am. Ind. Hyg. Assoc. J.* **1982,** 43; pp 395-399.

3. Kesavan, J.; Doherty, R.W. *Use of Fluorescein in Aerosol Studies*; ECBC-TR-103; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2001; UNCLASSIFIED Report (AD-A384058)